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An investigation of biogas production potential from livestock and slaughterhouse wastes

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ABSTRACT

Fossil fuel resources are severely limited and their combustion is a major source of environmental pollution. As a result, scientists avidly seek alternatives to fossil fuels, and biomass can be a viable alternative source of energy. Anaerobic digestion is one of way of converting biomass to biogas. Slaughterhouse wastes and animal husbandry residues are from among the organic waste types utilized to generate biogas. Every year, large amounts of livestock waste discharges and slaughterhouse waste materials are produced worldwide, which provoke environmental pollution and are thus a cause of much concern. In lieu of what is discussed, it is intelligent to use animal wastes to generate biogas and hence reduce pollution. In view of that, the researchers in this study intend to investigate biogas production potential from animal manure in Iran. To this aim, biogas production potential from heavy and light livestock and poultry wastes were examined. Slaughterhouse wastes, containing rumen, intestines, stomach and blood from heavy and light livestock, and also poultry blood were examined. The results indicate that biogas production potential from the available livestock manure in this country is 8600 million m^3 per year, 70% of which is obtained from heavy livestock, 23% of it from poultry, and only 7% from light livestock. Biogas yields potential from slaughterhouse wastes in Iran is approximately 54 million m^3 per annum of which 40% is produced from light livestock rumen, 24% from heavy livestock rumen, 17% from heavy livestock blood, 14% from poultry blood, and 5% from light livestock blood. Tehran Province, as the capital, had the greatest potential for biogas production from slaughterhouse waste; that is about 9 million m^3. From among all other provinces in Iran, Mazandaran Province had the greatest potential, with 828 million m^3 biogas yield per year.

Contents

1. Introduction

Iran is rich in different sources of energy. On the one hand, vast resources of non-renewable fossil fuels such as oil and gas

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reserves, belong to Iran, and on the other hand, it enjoys limitless potential for sustainable solar, geothermal, wind, hydrogen, and biomass energies [1]. Actually, renewable energies are becoming popular everywhere. For one thing, human population is to face fossil energy privation soon. For another, putrescible liquid and solid wastes (biomass) are abundant and the operation of biogas systems is quite simple. Therefore, many countries such as China, Germany, and Sweden have dedicatedly resorted to bio-energy production technology while China and India have installed biogas tanks in the rural areas [2]. The material that flows into the tanks facilitates the production of gas under anaerobic conditions. Once product pollution is minimized, it is used as an agricultural fertilizer [3–6]. Likewise, Industrial waste can also be anaerobically treated in biogas tanks. Besides generating biogas, this process helps reduce their environmental hazards. In 2011, biogas production potential in Iran through anaerobic technology has been about 16146 million m^3 [7]. However, livestock by-products, which are valuable resources of biogas [8], are not efficiently used in developing countries like Iran; While optimal use of livestock products such as intestines, blood, skin, etc. can develop industries, factories and jobs and thus prevent the loss of potentials and result in added value for slaughterhouses, they are discarded as waste and inappropriately processed. Moreover, biogas technology helps the society become healthier through dramatically cutting down on zoonotic disease transmission and consequently medical expenses [9]. Efficiently controlling odor emission from livestock manure and managing environmental hazards associated with livestock productions are some other problems that confront animal husbandries. Biogas technology, therefore, benefits societies by alleviating problems with slaughterhouse wastes and livestock manure, and also by generating a renewable energy source [10,11]. Several researchers have studied the potential of biogas production technology [12–19]. For example, Esen and Yuksel have investigated the benefits of using various renewable energy sources for heating a greenhouse in Turkey [20]. Iran is a vast country with approximately 164.8 million ha land, about 51 million of which is arable, and with 102 million ha of natural forests and pastures, 2700 km of maritime border, and about 120 billion m^3 of exploitable water [21]. It consists of 31 provinces with appropriate climate diversity (14 different types of climate) and in light of the inexhaustible solar energy and skilled human resources, there is a good potential for exploiting land for agricultural, horticultural, animal husbandry, poultry, and fish farming activities. Given the high production rate of the agricultural produce, the waste byproduct is also abundant and so can be used as one of the best sources of biomass [21]. The present paper examines the potential of biogas production from livestock and slaughterhouse wastes in Iran.

2. Materials and methods

2.1. Wastes

Livestock and poultry wastes are rich in organic matter and can be used as raw material for energy production in biomass power plants. Fresh waste, however, is more suitable [22]. In the present paper, livestock manure as well as the contents of rumen, intestines, stomach and the blood of slaughtered livestock were used as biomass.

2.2. Calculating the amount of excreta produced per livestock

To determine the amount of produced excreta, statistics of livestock population in each province were obtained from the Ministry of Agriculture and the Statistical Center of Iran. As shown in Table 1, the amount of feces and urine (produced excreta) depends on various factors such as weight, size, and age of the animal [23,24]. Some studies considered daily feces as 5%, 4% and 5% of the live weight of heavy livestock, light livestock and poultry, respectively [24]. In this paper, cow, calf, buffalo, and camel were considered as heavy livestock, sheep and goat as light livestock, and broilers, laying hens and pullets as poultry. The daily excreta was considered 9% of the weight of the heavy livestock, 4% of the weight of light livestock, and 3% of the weight of poultry. Table 2 describes the amount of excreta produced in each province. (Livestock weight was considered 250, 40, and 1.5 kg for heavy livestock, light livestock and poultry, respectively).

Table 1
Amount of excreta and urine in animal [23,24].

Animal	Excreta (kg)	Urine (kg)
Cow	23	9
Sheep	1.3	0.7
Horse	16	3
Poultry	0.01	0

2.3. Calculating the amount of blood and rumen contents obtained from slaughtered livestock

As a result of scientific and industrial developments, it is possible to process animal waste and remold it into very valuable end-products, especially in the developed countries [9,25]. A large percentage of livestock live weight consists of by-products (waste) which comprises about 65% of the total weight in the young and healthy animals and about 75% of the weight in the old livestock [9]. Table 3 presents the organs of the livestock and the ratio of their weight to the whole body. The number of slaughtered livestock per province in 2011 was obtained from the Ministry of Agriculture and the Statistical Center of Iran (see Table 4).

2.4. Calculating the amount of biogas produced

The amount of produced biogas depends on several factors, one of which is the feed type. Table 5 depicts the amount of biogas produced from different types of feed [24,26,27]. This amount may also vary for each experiment depending on the circumstances. Since animal excreta is not always available and it cannot be collected sufficiently, for producing biogas from excreta, availability coefficients of 50%, 13%, and 99% for heavy livestock, light livestock and poultry were considered, respectively [24]. The amount of total solids in the excreta was another factor affecting biogas production. Table 5 shows the amount of total solids in livestock waste and the amount of biogas produced from it. In this paper, the total amount of total solids was assumed 25% for heavy livestock, 25% for light livestock, and 29% for poultry. The amount of the produced biogas was therefore calculated to be 0.6, 0.4, 0.8 $m^3\,kg^{-1}$ of the total solids ($m^3\,kg^{-1}$ of TS) for heavy livestock, light livestock and poultry, respectively. It was also supposed that the waste was acquired from the same slaughterhouse and transformed into biogas without any loss of moisture. In this paper, the amount of biogas produced from blood and rumen contents was considered 0.3 $m^3\,kg^{-1}$ of fresh material.

3. Results and discussion

Each province's potential for producing fresh excreta by the end of 2011 is given in Table 2. According to the results, Fars,

Table 2
The total wet animals waste values of provinces in Iran according to the data in 2011.

Province	Wet waste potential						
	Heavy livestock		Light livestock		Poultry		Total
	million tons year^{-1}	%	million tons year^{-1}	%	million tons year^{-1}	%	million tons year^{-1}
Azarbaijan Sharghi	6.2	69	2.4	27	0.3	4	8.9
Azarbaijan Gharbi	5.1	66	2.3	30	0.3	4	7.7
Ardebil	3.6	71	1.4	27	0.1	3	5.1
Isfahan	5.0	70	1.4	20	0.7	10	7.2
Alborz	0.9	58	0.3	16	0.4	26	1.6
Ilam	0.4	27	1.1	69	0.1	5	1.6
Bushehr	0.4	26	1.1	70	0.1	4	1.6
Tehran	2.8	64	0.6	14	0.9	22	4.3
Chaharmahal va Bakhtiari	1.6	51	1.5	47	0.1	2	3.1
Khorasan Jonubi	1.0	38	1.5	57	0.1	5	2.6
Khorasan Razavi	3.5	46	3.5	47	0.5	7	7.5
Khorasan Shomali	0.9	39	1.4	60	0.0	1	2.3
Khuzestan	4.2	65	2.0	31	0.3	4	6.5
Zanjan	1.3	62	0.6	30	0.2	8	2.2
Semnan	0.8	42	0.8	44	0.3	15	1.8
Sistan va Baluchestan	1.7	52	1.5	46	0.1	2	3.2
Fars	3.2	34	5.7	62	0.3	4	9.2
Ghazvin	2.8	74	0.6	17	0.3	9	3.8
Ghom	0.9	59	0.4	28	0.2	13	1.6
Kordestan	2.1	65	1.0	30	0.2	6	3.2
Kerman	1.2	38	1.9	58	0.2	5	3.3
Kermanshah	2.0	55	1.5	41	0.2	5	3.7
Kohgiluye va Boyerahmad	0.6	36	1.0	62	0.0	2	1.6
Golestan	3.1	73	0.7	18	0.4	9	4.2
Gilan	3.3	73	0.6	12	0.7	15	4.6
Lorestan	2.3	47	2.5	50	0.1	3	4.9
Mazandaran	6.1	69	1.3	15	1.4	16	8.8
Markazi	2.2	67	0.9	26	0.2	7	3.3
Hormozgan	0.9	43	1.0	52	0.1	4	2.0
Hamedan	3.4	72	1.1	24	0.2	4	4.8
Yazd	1.3	64	0.6	28	0.2	8	2.0

Table 3
The organs of the livestock and their weight percent to the whole body [9].

Livestock	Weight	Product			
		Blood		Rumen	
		%	Amount (kg)	%	Amount (kg)
Heavy livestock	250	7	21	10	30
Light livestock	40	3	1.2	25	10
Poultry	1.5	3	0.045	0	0

Mazandaran and Azerbaijan-e Sharghi Provinces had a potential of over 8 million tons per year, while Azerbaijan-e Gharbi, Isfahan, Khorasan-e Razavi, and Khuzestan Provinces had a potential of 6–8 million tons annually. Next in rank would stand Ardebil, Lorestan, Gilan, Tehran and Hamadan Provinces which had a potential of 4–6 million tons per year, and other provinces had a potential of less than 4 million tons yearly. Fars had the highest potential to produce light livestock waste with 5.7 million tons of excreta. Azerbaijan-e Sharghi had the highest potential for heavy livestock waste production with 6.1 million tons of excreta, and Mazandaran had the highest potential for poultry waste production with 1.4 million tons of excreta. Calculations revealed that Iran has a total potential of 128 million tons for producing fresh livestock excreta, from which amount 58% would be from heavy livestock, 7% from poultry, and 35% from light livestock. Factors like availability of excreta and the amount of solid materials in it were taken into account when calculating the biogas production potential from livestock excreta. In 2011, 5 million tons of manure was produced in broiler and breeder poultry houses in Iran, which could be converted to about 1227 million m^3 of biogas through anaerobic technology, to be used as an energy source [28]. Table 6 illustrates the potential of biogas produced from livestock excreta. According to the results, Mazandaran Province had the greatest potential for biogas production from livestock excreta with about 828 million m^3 of biogas, of which 60% was from heavy livestock excreta, 2% from light livestock excreta, and 38% from poultry excreta. Azerbaijan-e Sharghi stood second with approximately 587 million m^3 of biogas produced. If the total potential of biogas production from animal excreta is considered, this country has the potential to produce about 8600 million m^3 of biogas, of which 70% will be from heavy livestock, 23% from poultry, and 7% from light livestock. Similar studies in Iran show the potential of biogas production from livestock waste as 8668 million m^3 per annum [29,30]. This dissimilarity could be due to differences in the conversion rate of waste into biogas and the production rate of waste per livestock. According to estimations, the energy potential of biogas generated from livestock waste in Iran equals 25,500 barrels of crude oil per year at present [31]. The production potentials of slaughterhouse waste for each province is shown in Table 4. According to the results, Tehran, Isfahan, and Khorasan-e Razavi Provinces have a biogas production potential from slaughterhouse waste of more than 20 thousand tons, while this potential is less than 10 thousand tons per year in other provinces. The largest number of livestock and poultry was slaughtered in Tehran Province, whereas the largest number of light livestock slaughter occurred in Isfahan Province. A study shows the potential of biogas production from cattle slaughterhouse waste

Table 4
The total slaughterhouse waste potential values of provinces in Iran according to the data in 2011.

Province	Slaughterhouse waste potential										
	Heavy livestock slaughter				*Light livestock slaughter*				Poultry slaughter		Total
	Blood 1000 tons year^{-1}	%	Rumen 1000 tons year^{-1}	%	Blood 1000 tons year^{-1}	%	Rumen 1000 tons year^{-1}	%	Blood 1000 tons year^{-1}	%	1000 tons year^{-1}
Azarbaijan Sharghi	1.8	23	2.6	32	0.3	4	2.5	31	0.9	11	8.0
Azarbaijan Gharbi	1.2	27	1.7	38	0.1	1	0.5	10	1.1	24	4.4
Ardebil	0.7	17	1.0	25	0.2	5	1.6	41	0.5	12	3.8
Isfahan	1.8	8	2.6	11	1.8	8	14.9	63	2.5	10	23.6
Alborz	0.6	16	0.8	23	0.1	4	1.0	30	0.9	27	3.5
Ilam	0.1	16	0.2	23	0.0	4	0.3	36	0.1	19	0.8
Bushehr	0.1	16	0.2	23	0.0	4	0.2	33	0.2	24	0.7
Tehran	5.0	17	7.1	24	1.6	5	13.3	45	2.8	9	29.8
Chaharmahal va Bakhtiari	0.3	14	0.4	20	0.1	6	1.0	47	0.3	12	2.1
Khorasan Jonubi	0.1	13	0.2	19	0.0	5	0.4	38	0.3	25	1.1
Khorasan Razavi	2.6	13	3.7	18	1.2	6	10.1	49	2.8	14	20.5
Khorasan Shomali	0.2	16	0.3	23	0.1	5	0.6	43	0.2	13	1.3
Khuzestan	1.7	18	2.5	26	0.5	5	4.3	45	0.6	7	9.6
Zanjan	0.4	27	0.6	38	0.0	2	0.2	14	0.3	20	1.7
Semnan	0.2	9	0.3	13	0.1	6	1.2	50	0.5	23	2.3
Sistan va Baluchestan	1.7	40	2.4	57	0.0	0	0.1	2	0.0	0	4.1
Fars	1.1	11	1.6	16	0.6	6	4.6	46	2.1	21	9.9
Ghazvin	0.7	26	1.0	37	0.1	2	0.5	18	0.5	18	2.7
Ghom	0.3	5	0.4	8	0.4	8	3.2	64	0.8	15	5.1
Kordestan	0.7	30	1.0	43	0.0	2	0.4	15	0.2	9	2.4
Kerman	0.8	17	1.2	25	0.2	5	1.9	41	0.5	11	4.6
Kermanshah	1.0	24	1.4	35	0.1	3	1.1	27	0.4	11	4.1
Kohgiluye va Boyerahmad	0.1	7	0.1	9	0.1	8	0.9	71	0.1	5	1.3
Golestan	0.4	10	0.6	14	0.1	4	1.2	30	1.7	43	3.9
Gilan	1.8	26	2.6	37	0.1	2	1.2	17	1.3	18	7.0
Lorestan	1.2	25	1.7	35	0.1	3	1.2	25	0.6	12	4.7
Mazandaran	1.5	19	2.2	27	0.3	3	2.4	29	1.8	22	8.2
Markazi	0.6	17	0.9	24	0.1	4	1.2	34	0.8	21	3.6
Hormozgan	0.4	25	0.6	36	0.0	2	0.3	17	0.3	19	1.7
Hamedan	0.8	21	1.1	30	0.1	4	1.2	32	0.5	13	3.6
Yazd	0.3	10	0.5	14	0.3	7	2.1	59	0.4	11	3.6

including rumen, stomach, and intestines in Iran to be about 200 thousand tons per year [32]. According to the selected conversion coefficients, the amount of biogas produced from slaughterhouse waste was calculated (see Table 7). The results show that Tehran Province has the highest potential for biogas production from slaughterhouse waste with approximately 9 million m^3 of biogas of which 45% was produced from rumen fluid of light livestock, 24% from rumen fluid of heavy livestock, 17% from heavy livestock blood, 9% from poultry blood, and 5% from the blood of light livestock. Calculations also show that the potential for biogas production from slaughterhouse waste in Iran is approximately 54 million m^3 per year, of which 40% is produced from rumen contents of light livestock, 24% from rumen contents of heavy livestock, 17% from heavy livestock blood, 14% from poultry blood, and 5% from light livestock blood. In a similar study, the potential for biogas production from the rumen contents collected from slaughtered cows in Iran was estimated to be 4.5 million m^3 [32].

Table 5
The amount of biogas produced from different substrates [24,26,27].

Substrates	DM [%]	Biogas yield [$m^3\ kg^{-1}$ of TS]
Excreta from cattle (fresh)	25–30	0.6–0.8
Excreta from sheep (fresh)	18–25	0.3–0.4
Excreta from poultry	10–29	0.3–08
Blood liquid	18	0.3–0.6
Rumen content	12–16	0.3–0.6

Conclusion

In addition to energy crisis and limited fossil fuel resources, widespread use of non-renewable fuels causes severe environmental problems such as water pollution and air pollution and consequently leads to global warming. Therefore, to maintain a healthy environment, which is the most important prerequisite for sustainable economic development, replacing fossil fuel resources with renewable energy is a necessity. Biomass energy is a renewable energy source highly regarded because of its various benefits. As the main sources of biomass, livestock husbandries and slaughterhouses are essential for creating economic development opportunities. The results obtained from this study indicate that 8600 million m^3 of biogas can be produced in Iran from livestock excreta annually. The greatest potential belongs to Mazandaran Province with 828 million m^3 per year. The biogas generated can be burned to produce heat and electricity or it may be converted into bio-methane, which is as valuable as natural gas and other fuels. Bio-methane is ozone friendly and sustainable, usually consisting of 95% methane, and can be used along with natural gas for electricity generation, heating, cooling, pumping, or even as car fuel. According to the results, by the end of 2011, biogas production potential from slaughterhouse waste in Iran has been 54 million m^3. The highest biogas production potential from slaughterhouse wastes belonged to Tehran Province with 9 million m^3. Although slaughterhouse wastes are less frequently used to produce biogas than livestock excreta, production of biogas from these wastes may result in the establishment of new factories which secures new working positions for many,

Table 6
Available animal waste biogas potential values of provinces in Iran according to data in 2011.

Province	Biogas potential						
	Heavy livestock		Light livestock		Poultry		Total
	million m^3 $year^{-1}$	%	million m^3 $year^{-1}$	%	million m^3 $year^{-1}$	%	million m^3 $year^{-1}$
Azarbaijan Sharghi	498.2	85	30.9	5	58.0	10	587
Azarbaijan Gharbi	410.5	84	30.0	6	49.2	10	490
Ardebil	294.0	88	18.0	5	21.6	6	334
Isfahan	408.9	75	18.3	3	120.1	22	547
Alborz	73.1	51	3.3	2	66.1	46	142
Ilam	34.2	52	14.2	22	17.1	26	65
Bushehr	33.5	54	14.3	23	13.7	22	62
Tehran	225.2	50	7.9	2	214.4	48	448
Chaharmahal va Bakhtiari	128.4	80	18.9	12	13.6	8	161
Khorasan Jonubi	78.9	61	19.1	15	32.2	25	130
Khorasan Razavi	280.3	64	45.8	10	112.0	26	438
Khorasan Shomali	73.1	76	18.0	19	5.3	6	96
Khuzestan	342.7	80	26.3	6	58.5	14	428
Zanjan	109.3	69	8.4	5	39.9	25	158
Semnan	61.7	46	10.5	8	61.2	46	133
Sistan va Baluchestan	134.4	80	18.9	11	15.0	9	168
Fars	257.1	63	74.2	18	78.3	19	410
Ghazvin	230.1	73	8.4	3	76.9	24	315
Ghom	75.9	58	5.8	4	48.6	37	130
Kordestan	167.9	76	12.4	6	41.3	19	222
Kerman	99.9	63	24.4	15	35.1	22	159
Kermanshah	162.1	73	19.4	9	40.4	18	222
Kohgiluye va Boyerahmad	46.3	69	12.9	19	7.7	12	67
Golestan	248.3	72	9.6	3	84.9	25	343
Gilan	268.9	62	7.4	2	154.8	36	431
Lorestan	187.5	75	32.1	13	31.8	13	251
Mazandaran	493.1	60	17.0	2	317.6	38	828
Markazi	179.8	74	11.4	5	50.8	21	242
Hormozgan	70.0	68	13.6	13	19.6	19	103
Hamedan	279.4	83	14.8	4	43.9	13	338
Yazd	106.9	71	7.4	5	37.0	24	151

Table 7
Slaughterhouse waste biogas potential values of provinces in Iran according to the data in 2011.

Province	Biogas potential											
	Heavy livestock slaughter				Light livestock slaughter				Poultry slaughter		Total
	Blood million m^3 $year^{-1}$	%	Rumen million m^3 $year^{-1}$	%	Blood million m^3 $year^{-1}$	%	Rumen million m^3 $year^{-1}$	%	Blood million m^3 $year^{-1}$	%	million m^3 $year^{-1}$
Azarbaijan Sharghi	0.5	23	0.8	32	0.1	4	0.7	31	0.3	11	2.4
Azarbaijan Gharbi	0.4	27	0.5	38	0.0	1	0.1	10	0.3	24	1.3
Ardebil	0.2	17	0.3	25	0.1	5	0.5	41	0.1	12	1.2
Isfahan	0.6	8	0.8	11	0.5	8	4.5	63	0.7	10	7.1
Alborz	0.2	16	0.2	23	0.0	4	0.3	30	0.3	27	1.0
Ilam	0.0	17	0.1	24	0.0	4	0.1	36	0.0	19	0.2
Bushehr	0.0	16	0.0	24	0.0	4	0.1	33	0.0	24	0.2
Tehran	1.5	17	2.1	24	0.5	5	4.0	45	0.8	9	8.9
Chaharmahal va Bakhtiari	0.0	21	0.1	29	0.0	1	0.0	4	0.1	45	0.2
Khorasan Jonubi	0.1	14	0.1	20	0.0	6	0.3	47	0.1	13	0.6
Khorasan Razavi	0.0	4	0.1	6	0.0	1	0.1	11	0.8	78	1.1
Khorasan Shomali	0.8	15	1.1	21	0.4	7	3.0	57	0.1	1	5.4
Khuzestan	0.1	12	0.1	17	0.0	4	0.2	32	0.2	35	0.5
Zanjan	0.5	18	0.7	26	0.2	6	1.3	46	0.1	4	2.8
Semnan	0.1	24	0.2	34	0.0	1	0.1	12	0.2	28	0.6
Sistan va Baluchestan	0.1	12	0.1	17	0.0	8	0.3	63	0.0	1	0.5
Fars	0.5	27	0.7	38	0.0	0	0.0	1	0.6	34	1.9
Ghazvin	0.3	13	0.5	19	0.2	7	1.4	55	0.1	6	2.5
Ghom	0.2	23	0.3	33	0.0	2	0.1	16	0.2	26	0.9
Kordestan	0.1	6	0.1	8	0.1	9	1.0	72	0.1	5	1.4
Kerman	0.2	27	0.3	39	0.0	2	0.1	14	0.2	19	0.8
Kermanshah	0.2	18	0.3	25	0.1	5	0.6	42	0.1	10	1.4
Kohgiluye va Boyerahmad	0.3	27	0.4	38	0.0	4	0.3	30	0.0	2	1.1
Golestan	0.0	3	0.0	4	0.0	4	0.3	31	0.5	58	0.9
Gilan	0.1	11	0.2	16	0.0	4	0.3	33	0.4	36	1.1
Lorestan	0.5	29	0.8	41	0.0	2	0.4	19	0.2	9	1.9
Mazandaran	0.3	20	0.5	28	0.0	2	0.3	20	0.5	30	1.8
Markazi	0.5	21	0.7	31	0.1	4	0.7	33	0.2	11	2.1
Hormozgan	0.2	19	0.3	27	0.0	5	0.4	39	0.1	10	1.0
Hamedan	0.1	24	0.2	34	0.0	2	0.1	16	0.1	25	0.6
Yazd	0.2	22	0.3	31	0.0	4	0.3	32	0.1	11	1.1

preventing the loss of social potentials in different regions. Value added for slaughterhouses is a further benefit of this technology. Moreover, people would enjoy a healthier society for dramatic reduction of medical expenses associated with transmission of zoonotic diseases.

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